

GARP ATLANTIC TROPICAL EXPERIMENT AND RADIATION
FACTORS IN THE WEATHER AND CLIMATE

K. L. Kondrat'yev

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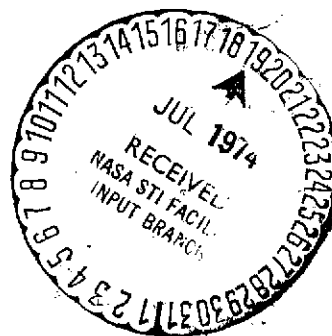
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16. Abstract The basic features of the energetics of the tropical atmosphere and the role of radiation factors in formation of the most typical meteorological formations of the lower latitudes (convective cloudiness and cloud clusters, tropical waves, etc.) are surveyed. Considerations are advanced regarding the position of the GATE radiation subprogram (RPA) in the total array of observations, and the most important divisions of RPA are examined in this context. It is demonstrated that special aircraft laboratories should be used as a decisive means of conducting RPA.			
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GARP ATLANTIC TROPICAL EXPERIMENT AND RADIATION
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K. L. Kondrat'yev¹

Introduction

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The intensive development of a primary trend in modern meteorology, one associated with advanced calculation of atmospheric processes and phenomena from the viewpoint of their interaction with the underlying surface is setting increasingly broader requirements for allowance for new plus factors determining the processes and phenomena in question. It has by now become customary, for example, to utilize the complete system of hydrodynamic and thermodynamic equations in numerical-term forecasting. The problem of energetics and allowance for nonadiabatic factors should be regarded as the central in numerical simulation of total atmospheric circulation. It has long since become clear that an adequate theory of climate can be constructed only on the basis of sufficiently correct simulation of circulation and of various forms of heat and moisture budget in the atmosphere. To a considerable extent all these circumstances determine, in particular, the goals and tasks of GARP, including the GARP Atlantic Tropical Experiment (GATE).

Radiative transfer in the atmosphere is, of course, one of the processes exerting the greatest influence on the thermodynamics of the atmosphere. Calculation of the heat radiation influx as a prominent component of the intersects of the "underlying surface-atmosphere" system has become an integral part of numerical simulation of total atmospheric circulation and climate theory. The development of the theory of forecasting of missile meteorological phenomena dictates the need for detailed calculation of radiation factors in the description and forecasting of such phenomena as thermal convection, the formation of convective cloudiness, small-scale interaction between the atmosphere and the underlying surface, and so forth. Construction of a theory of turbulent mixing in the boundary layer of the atmosphere on the basis of use of a closed system

¹Corresponding member of the Academy of Sciences of the USSR.

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of hydrodynamic and thermodynamic equations has shown clearly that disregard of radiation effects is not justifiable [20]. Study of the interaction between turbulent and radiative transfer in the ground layer of the atmosphere has led to the same conclusion [15, 18].

The current status of the theory of radiative transfer in the atmosphere is characterized by an abundance of varied methods, which have been proposed in particular for calculation of radiant energy flux. At first glance the picture of the broad spectrum of methods, ranging from the highly approximate ones to the practically precise ones permitting "standard" calculations, would appear to be entirely satisfactory. The situation is the opposite, however, for two reasons: (1) not even an initial classification of methods has been made, one based on comparison of the latter (with identical input data) and evaluation of their accuracy and limits of applicability: (2) virtually no correct comparison has been made between calculation procedures and experimental methods: (3) the complexity of the real atmosphere, which is determined primarily by the irregularity of the spatial structure and variation in cloud and aerosol properties, renders it extremely difficult to allow for radiation factors from the basis of a "pure" theory and imposes the task of elaborating methods of semi-empirical parametrification involving the use of the existing data of large-scale observations (the cumbersome nature of theoretical calculations, which sometimes goes beyond permissible limits, is also of considerable weight).

In view of the current circumstances allowance for radiation factors in problems of atmospheric dynamics (the problem of interaction between radiation and dynamics) may (and indeed is) found to be inadequate, although a very laborious process. The existing difficulties can be overcome only by "regularizing" the calculations procedures on the basis of comparison of these procedures with experimental methods and by developing methods for the parametrification of radiation effects. Solution of this problem is one of the goals of GATE.

The Atlantic Tropical Experiment of GARP (GATE) is a major international program preceding the first global GARP program [1, 10-13, 22]. Analyses of the GATE plans (cf. [22]) shows that the Soviet Union is making an extremely important contribution to the accomplishment of this program. This is indicated also by the successful completion in 1972 of a major joint agency expedition under

the TROPEX-72 national tropical experimental program [12]. As we know, GATE is scheduled to be conducted between 15 June and 30 September 1974 in the equatorial region of the Atlantic. The GATE program incorporates all five subprograms relating to the following divisions of research: (1) synoptic scale atmospheric processes; (2) the boundary layer of the atmosphere; (3) convection and cloudiness; (4) radiation; and (5) oceanography. The responsibility of the individual central institutions (and countries) has been defined for each of these divisions. In particular, these institutions must act as centers for the collection and dissemination of GATE data in the corresponding research divisions. The Central Geophysical Observatory has been assigned the responsibilities of a central institution in the radiation subprogram of GATE (RPA). This means, of course, that Soviet specialists have been called upon to perform the most important part of the work relating to conduct of RPA. The situation is complicated by the fact that, because of the loss of the NASA Convair 990 aircraft laboratory, the bulk of the work connected to RPA falls to the two Soviet Il-18 flying laboratories.

The prominent role of Soviet specialists in the conduct of RPA is determined by the high level (and international prestige) of the radiation research being conducted in our country. The longest tradition in this field is that of the A. I. Voyeykov Central Geophysical Observatory, which celebrated its 125th anniversary in 1974. An adequate foundation for establishing the prominent role of the Soviet Union in RPA was laid by conduct of the KENEX program | starting in 1970 [5], and in particular the KENEX-73 maritime expedition in] the area of the Caspian Sea, the program of which represents the prototype of RPA. The particularly great responsibility for RPA determines the need for discussion of the divisions of the GATE tasks relating to the role of the radiation factors of weather and climate. Attention must be concentrated on these tasks in RPA, but it is no less important to ascertain the "boundary" problems determining the need for coordinated conduct of the various GATE subprograms.

A large number of items in the literature have been devoted to discussion of the problems of radiation factors in weather and climate (for example, see [3, 6, 14, 24, 25, 30]. The BOMEX [19, 37] and KENEX [5] programs represent/

RPA prototypes which have been applied in practice. There is no need to repeat the considerations and conclusions, which may be found in the literature referred to. Hence we shall restrict ourselves simply to examination of the specific aspects of RPA and its relationship to other GATE subprograms. The specific nature of RPA is determined by two circumstances: (1) the general trend toward fuller allowances for the factors determining change in weather and climate [8, 9]; (2) the particular features of the meteorological conditions of the equatorial regions of the Atlantic (high air temperature and humidity), flows of dust and sand from the continent of Africa, and so forth); (3) the close relationship between radiation and other factors in the thermodynamics of the tropical atmosphere.

The most natural thing to do would be to arrive at an analysis of the role of interaction of radiation and other factors in works devoted to studies of the patterns of atmospheric circulation in the tropics. We may point out in this context that the basic task of GATE is to investigate the aspects of tropical meteorology which are of great importance from the viewpoint of understanding the patterns of general circulation of the atmosphere of the planet (see [22]). The chief reasons for concentrating attention on the tropics lies in the fact that they represent the basic source of energy for total atmospheric circulation [38]. This alone reveals the close interrelation of the various sources and discharges of heat (it is important in particular to determine how the latent heat of condensation liberated in the process of formation of the convective region in the equatorial trough and has been "stored" in the tradewinds, is converted to the kinetic energy of the atmosphere in the temperate latitudes [11, 12]).

While the basic initial source of heat is represented by the solar radiation absorbed by the atmosphere and (above all) by the oceans, the energy of tropical disturbances is drawn primarily from the latent heat of condensation of water vapor in the free atmosphere, and the primary role is consequently played by the processes of interaction between the atmosphere and ocean, which in the boundary layer of the atmosphere are manifested in the form of turbulent and convective transfer of heat, moisture, and momentum. Convective clouds and cloud clusters, and the interaction of atmospheric waves of different scales,

are the most graphic indicators of these energy conversion processes of decisive value in the total circulation of the atmosphere of the planet. Unfortunately, / 99 the literature devoted to the energetics of the tropical atmosphere does not reveal to a sufficient extent the role and interaction of the various factors, and thus do not contain sufficiently clearcut indications regarding the decisive aspects of the GATE program. This is shown the most clearly by the example of RPA.

Certain Aspects of the Energetics of the Tropical Atmosphere

As is pointed out in the GATE program [22], the following are the most important physical factors associated with interaction of the phenomena of various scales and requiring elaboration of corresponding parametrification systems:

In the Atmosphere

- radiative transfer,
- small-scale turbulent transfer (vertical and horizontal) in the free atmosphere,
- processes in the ground and boundary layers,
- moist convection in cumulus clouds,
- large-scale condensation,
- the macroscale features of orography.

At the Level of the Underlying Land Surface

- hydrologic processes,
- heat exchange in the soil.

In the Ocean

- radiative transfer,
- small-scale turbulent transfer.

It is significant that the list of factors presented above is headed by radiative transfer problems. Let us now consider, taking as a basis certain studies of the energetics of the tropical atmosphere, just what studies of this

kind reveal about radiation factors and how these factors are taken into account. As has already been noted, one of the fundamental divisions of tropical meteorology involves the study of waves. There are four possible direct sources of energy for tropical waves: (1) the baroclinic instability determined by the horizontal temperature gradient; (2) the barotropic instability due to the meridional shift of the wind; (3) the second order conventional instability depending on release of the latent heat of condensation; (4) the temperate latitudes. J. Padro [28] investigated the relative role of the first three sources of energy on the basis of consideration of a four-layer model of the atmosphere and constructed a system of energy conversions in which allowance is made for the radiant influx of heat due to long-wave radiation, the influx being parametrized by use of the Newtonian law of cooling.

Figure 1 illustrates the cycles of energy conversions relating to the fourth and fourteenth days of the numerical experiments. It is to be seen that the radiative cooling is one order of magnitude lower than the latent heat of condensation. It may be inferred from this that radiation plays a secondary part and thus there is no particular need for conducting RPA to study the energetics of the processes of formation and development of tropical waves. The cycle of energy conversions considered in [28] fails, however, to contain an important element, that of the primary source of energy in the form of shortwave radiation absorbed by the underlying surface and the atmosphere. The method of allowing for longwave radiative heat transfer is also too approximate in nature. Hence it is clear that the conclusions of the paper in question in reality do not controvert the need for taking radiation factors into account. This is indicated by a paper by R. Read and R. Recker [32], which is devoted study of tropical waves in the equatorial portion of the western Pacific. According to the data of [32], the amplitude of temperature variations associated with waves does not exceed 0.5°C , i.e., it is smaller than the value of radiation cooling in 24 hours (in this work as well consideration is restricted entirely to the longwave component of the radiative heat flux). The authors of [32] arrived at the conclusion that in the wave crest areas the radiative temperature changes exceed the influences of two heat fluxes and remains substantial in the trough regions.

M. Yanai, S. Esbensen, and Chu. Jan-hwa [39] have studied the dynamics of another important phenomenon observed in the tropics, cloud clusters. On the basis of the data of observations and on that of theoretical simulation they have made an analysis in this paper of the conditions of formation and development of cloud clusters from the viewpoint of evolution of the heat and moisture budgets. Conversion of the heat flux equation yields the following formula for the total heat flux, Q_1 , in the case in question:

$$Q_1 = Q_R + L(c - e) - \frac{\partial}{\partial p} s' \omega' \quad (1)$$

in which Q_R is the radiative heat flux; quantity $L(c - e)$ determines the heat flux due to phase conversions of water (c - condensation, e - evaporation); term

$-\frac{\partial}{\partial p} s' \omega'$ ($s = c_p T + gz$), ω is the vectorial p velocity, and the primes denote that deviations from values averaged in the horizontal plane are intended) /100
characterizes the turbulent heat flux.

The main conclusion of [39] is that the zone of cloud clusters contains sections of descending movement, the need for which is determined by the circumstance that convergence is not of a scale large enough to ensure the observed mean vertical flow of the mass in the clouds. The descending movements of the clouds are responsible primarily for heating of the surrounding air by adiabatic compression. An important component of the heat budget of the surrounding air is represented by cooling due to evaporation of the liquid water "discharged" by the clouds. The decrease in air humidity in the descending movement sections is compensated by intensive transfer of vaporized and liquid moisture from the non-nimbus cumulus clouds situated in the lower part of the troposphere, which maintain the growth of the thick cumulonimbus cloud cover.

Although it is obvious that the dynamics of the processes of formation and development of cloud clusters is determined primarily by the influence of the vertical movements and phase conversions of water, the data of [39] indicate the need for taking the radiative heat flux into account. Following tradition in restricting themselves to allowance for long-wave radiation cooling and borrowing its values from the data of climatologic calculations (see [21, 23]), the authors of [39] note that the radiative cooling amounts to 1-2° per day. The heat flux due to condensation varies over a wide range, reaching the maximum /101
value of 6.4° per day at the 475 mb level. Probably the most convincing

illustration of the role of the radiant heat flux is determination of the vertical turbulent heat flux as a residual term of the heat budget equation with allowance and with no allowance for radiative cooling (cf. [35]). An example of this kind is shown in Figure 2 and requires no comment. The results obtained by T. Nitta and S. Esbensen [27] on the basis of the Barbados Oceanographic and Meteorological Experiment (BOMEX), which are shown in Figure 3, are also highly instructive.

Yet another illustration of the question of the role of radiation factors in the convection development process is represented by the work by S. Trago [35]. The existing theoretical models of thermoconvection clouds not allowed for the influence of radiation factors; this is quite natural in the case of sufficiently dense opaque clouds the formation of which is determined by mixing and phase conversion processes. However, not all clouds are opaque, and sometimes the formation of thermals is not accompanied by condensation. In this context a study is undertaken in [35] of the role of the longwave radiative cooling in the process of evolution of an ascending thermal "particle" on the basis of comparison of convective cooling (with no allowance for the effective radiation) and radiative cooling determined by disregarding the dynamics, extreme cases being assumed for the major thermal (major optical thickness) and minor thermal (minor optical thickness). Specific calculations are carried out for the values of parameter $l_c = w_r$ (w being the vertical rate and r the radius of the thermal). The values found are $5 \text{ m}^2/\text{sec}$ (weak convection), $5 \cdot 10^2$, and $5 \cdot 10^4 \text{ m}^2/\text{sec}$ (strong and very strong convection), which applied to the conditions of the Earth's atmosphere, the layer of the atmosphere of Venus near the upper boundary of the cloud cover, and the upper atmosphere of Mars.

In the case of the terrestrial convection cloud the ratios of radiative to convective cooling in the thermal damping stage are $5.2 \cdot 10^{-5}$, $5.2 \cdot 10^{-3}$, and $5.2 \cdot 10^{-1}$, respectively, for very strong, strong, and weak convection conditions. The influence of radiative cooling is substantial in all cases during the initial phase of thermal evolution, but subsequently convective cooling rapidly begins to predominate.

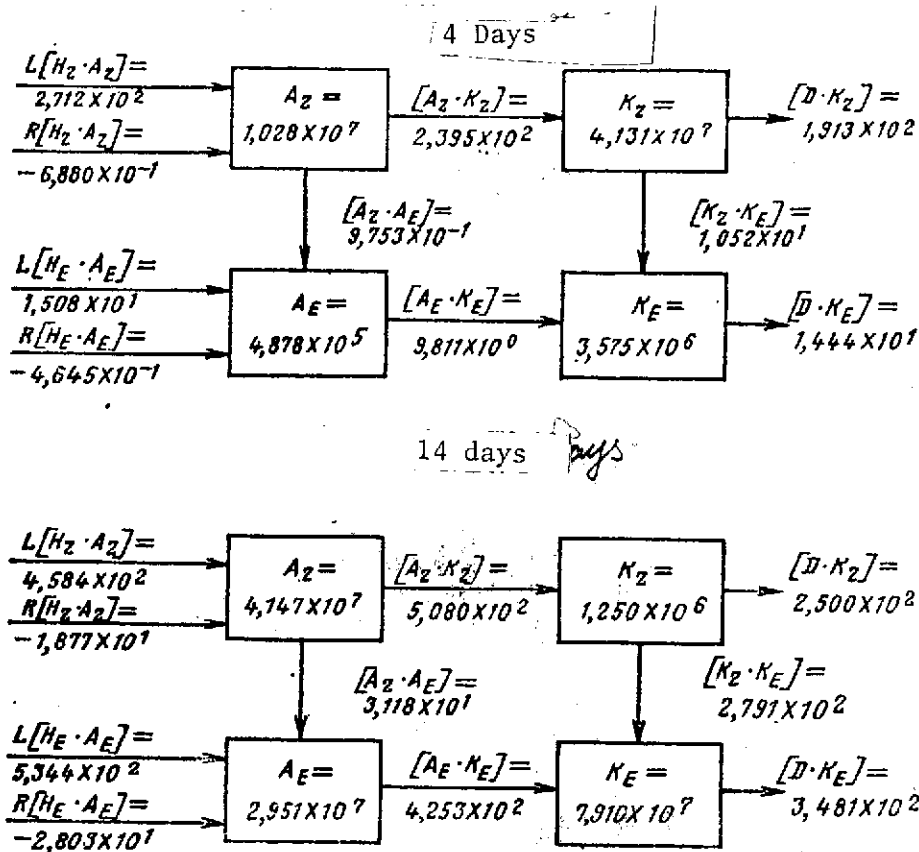


Figure 1. Cycle of Energy Conversions Determining Conditions of Existence of Tropical Waves (All Values are Expressed in erg/cm^2 or $\text{erg}/(\text{cm}^2 \cdot \text{sec})$. A_z , A_E are respectively the available zonal and eddy potential energy; K_z , K_E are the zonal and the eddy kinetic energy. $[A_z \cdot K_z]$ is the conversion of A_z to K_z ; the notation $[K_z \cdot K_E]$, $[A_E \cdot K_E]$, $[A_z \cdot A_E]$ is similar in meaning; $L[H_z \cdot A_z]$, $L[H_E \cdot A_E]$ is the conversion of the zonal and eddy components of the latent heat of condensation into A_z and A_E respectively; $R[H_z \cdot A_z]$, $R[H_E \cdot A_E]$ is the conversion of the zonal and eddy components of the radiation heat flux to A_z and A_E respectively. $[D \cdot K_z]$, $[D \cdot K_E]$ is the dissipation of the zonal and the eddy kinetic energy. Note: Commas equal decimals.

On the basis of comparison of the data indicated above, the conclusion is drawn in [39] that it is necessary to incorporate in the program of observations measurements of the vertical profiles of radiative cooling (longwave radiation fluxes). It is of course clear that this conclusion is somewhat

one-sided, inasmuch as in reality measurements of the vertical profiles both of longwave and of shortwave components of the radiation budget are heated. It is also beyond question that solution of the main GATE problem; which consists in arriving at an understanding of the tropical convection mechanism and its interaction with large scale circulation (the "core" of its problem is the matter of cloud clusters), calls for close coordination of virtually all the GATE subprograms, and accordingly the conduct of coordinated (synchronous) observation programs. Certain considerations relating to this question are advanced in RPA [35].

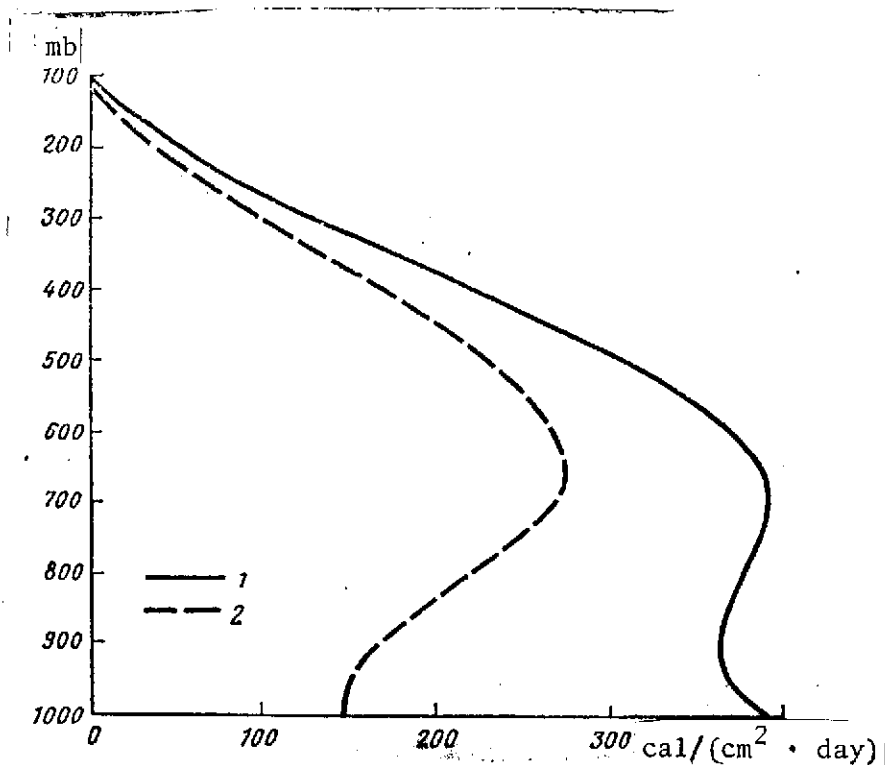


Figure 2. Vertical Profile of Turbulent Flux in the Troposphere. 1, With allowance made for radiative cooling; 2, with no allowance for radiant heat flux.

The examples given above of study of the main phenomena taking place in the tropical atmosphere (discussion has not been devoted merely to problems relating to study of the convergence zone within the tropics) make it possible to regard the existence of RPA necessary in its interrelation with other GATE subprograms and to assume the chief content of RPA to be the gathering of data on the vertical profiles of the radiation budget and its components in the troposphere.

To solve this problem RPA must include radiation measurements involving the use of such facilities as ships, airplanes, captive balloons, ground stations, sea buoys, actinometric radiosondes (ARS), and satellites. Measurements of the heat budget of the ocean's surface, as well as underwater measurements can be made from ships buoys. In this instance the role of the buoys must be that of performing measurements of the radiation budget and its components in accordance with a complete program. This is impossible from ships, since the influence of the hull of a vessel renders measurements of the radiation budget and its longwave component undependable.

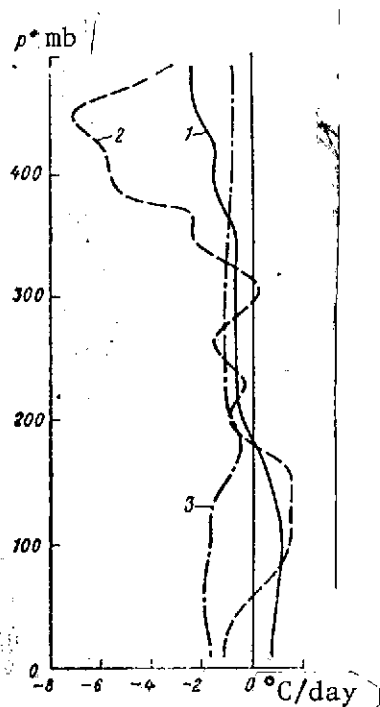


Figure 3. Vertical Profiles of Heat Fluxes (Expressed in $^{\circ}\text{C}/\text{Day}$), Based on the Data of Observations for 28-29 June 1969 During a Period of Intensive Development of Cumulus Clouds. 1, Total heat flux; 2, heat flux due to phase conversions of water; 3, radiant heat flux ($p^*=p_s-p$, in which p_s is the pressure at sea level).

The data of weather satellites afford information on cloud fields, fluxes of escaping radiation, and the temperature of the underlying surface (remote probing of the atmosphere will also be conducted from certain satellites). Combined utilization of the data of ships and satellite measurements makes it possible to gain information on the radiative heat flux for the entire thickness of the atmosphere on scale A, B, and C [22].

Actinometric radiosondes and aircraft must play an extremely important role as vertical probing facilities. This is particularly true of the actinometric radiosondes, since they can be launched under any weather conditions, while airplanes can perform measurements only outside the convective cloud cover: between clouds, and below and above clouds (if the

latter is possible). The extensive available materials obtained from nighttime actinometric radiosondes attest to the great complexity and variability of the thermal radiation field in the free atmosphere of the tropics (see [25]). It

would be of great value to apply a similar procedure for recreation probes in daytime. However, there have thus far been no attempts at utilization of daytime actinometric radiosondes: only tests of the first models of daytime actinometric radiosondes have been initiated and are to continue during the GATE. In view of this situation, a special role in the conduct of RPA and GATE as a whole must be assigned to aircraft laboratories performing both radiation measurements and a broad array of concomitant measurements. This encourages the devotion of particular attention to discussion of the array of aircraft measurements and the potential and features of the aircraft measurement method. A detailed summary discussing this problem area has been prepared by E. Zipser [40], and the possible goals and methods of aircraft radiation measurements within the framework of RPA have been discussed by M. R. Boellot [31].

Aircraft Laboratories as a Precise Means of Conducting RPA

As has already been pointed out, the aircraft portion of RPA (as well as RPA as a whole) must be based on the experience gained in carrying out the BOMEX and KENEX programs. Thus it is necessary to discuss only the specific features of conduct of comprehensive measurements of this kind under tropical conditions. First of all it is obvious that aircraft measurements can be performed only for phenomena of scales B($10^2 - 10^3$ km) and C($10 - 10^2$ km) and only on the basis of extrapolation is it possible to obtain information characterizing the influence of radiation factors on phenomena of scale A($10^2 - 10^3$ km). We may note in this context that elaboration of interpolation methods involving the use of satellite data on the distribution and characteristics of clouds is of great importance in making an interpolation of this kind. According to [35] an accuracy of measurement of the radiant heat flux of the border of 10% is desirable and altitude (pressure) resolution, which amounts to $\Delta p = 200$ mb (greater detail is of course desirable within the boundary layer of range). /103

The KENEX shows that such accuracy is difficult to achieve even with a cloudless atmosphere. Only the GATE experiment, of course, will show thought accuracy can actually be achieved in radiation measurements under the complex conditions of a tropical atmosphere with convective clouds present. It is clear that aircraft measurements of the vertical profiles of radiation fluxes can be

sufficiently dependable only in the case of a horizontally homogeneous atmosphere (cloudless sky or extensive unbroken cloud). When convective clouds are present dependable data can be obtained only by means of a "column" of several airplanes performing coordinated flight at several levels and corresponding synchronous measurements (in effect, quasisynchronous ones). Experience has shown, however, that the conduct of such synchronous (or even quasisynchronous) measurements is a highly complex problem both from the viewpoint of piloting the aircraft and that of assuring that the results obtained will be comparable. Thus it must be kept in mind that "individual" probes or virtually synchronous measurements involving the use of no more than 2-3 airplanes are the most reliable.

An important feature of the aircraft portion of RPA consists in the fact that it is not restricted to measurements of the integral shortwave and long-wave radiation fluxes, but rather includes spectral measurements over a broad wavelength range as important components, and also provides for measurement of aerosol characteristics and cloud microstructure parameters. It is correctly pointed out in the international RPA [35] that the performance of an array of measurements of this complexity is impossible without the outfitting of special flying "radiation" laboratories, the more so since the program of these laboratories must also include certain area associated with study of optical properties (in particular, the spectral albedo) of clouds, the underlying surface, the aerosol, and the transparency of the atmosphere. The array of spectral measurements of radiation fluxes and of a transparency of the atmosphere and the aerosol is of particular interest in connection with the specific feature of the atmosphere of the equatorial region of the Atlantic represented by the influence of flows of sand and dust from Africa (see [6]).

As was observed during the dust storm on Mars at the end of 1971 and the beginning of 1972 [7], the higher dust content of the tropical atmosphere due to the flow of dust and sand from the desert caused intense heating of the air going to absorption of solar radiation, and this heating can exert a substantial effect on development of convection. The high moisture content and dust content of the tropical atmosphere are the reasons for its normally low transparency, in particular in the 8-12 μ of water vapor window, which is utilized to determine the temperature of the ocean's surface on the basis of data from measurements

of escaping radiation performed by satellites. Inasmuch as the temperature of the ocean's surface is a fundamental parameter in long-range weather forecasting (see [8]), study of the transparency of the atmosphere in the 8-12 μ window and determination of the factors determining it (particular attention must be devoted to determination of the role of dimers of water vapor molecules [26]) must become an important component of the aircraft measurement program.

It is to be pointed out in this context that the problem of indirect probing of the tropical atmosphere from satellites also calls for special attention. It may be assumed that RPA will make a substantial contribution to solution of this problem as well. Study of aerosol radiation effects under tropical atmospheric conditions is unquestionably of great interest also from the viewpoint of study of the factors determining contemporary climatic changes [2, 6, 16, 17].

As has already been noted, under the conditions of the complex cloud field of the equatorial region of the Atlantic is virtually impossible to obtain adequate information with only one "radiation" airplane available. At least two flying laboratories of the same type are needed for the conduct of RPA; they should be used for other purposes only if such impossibility exists. In view of the fact that the Soviet Union has been assigned the basic publications in the conduct RPA and subsequent collection and dissemination of the data obtained, the use primarily of two Soviet Il-18 aircraft laboratories for purposes of RPA should be regarded as entirely justified. Only if this is done will it be possible to obtain sufficiently dependable data on the radiation heat flux in the presence of the horizontal heterogeneity of the atmosphere due to cloudiness. Synchronous probing of the atmosphere by two airplanes provides such a possibility, on the condition that careful comparisons have been made of the equipment in advance.

With two identical airplanes available, it is also impossible to carry out synchronous comparative probing above the oceans and continents, which is of great importance for performing the GATE missions. (The data of the expedition conducted under the BOMEX program have shown [27] that the great amplitude of the diurnal variation in temperature, wind, horizontal divergence, relative eddy, and vertical component of the wind speed is due chiefly to the contrasts between ocean and land.) The availability of two airplanes makes it

possible to obtain more extensive observation materials for various technical conditions (VTZK, cloud clusters, crests and troughs of tropical waves, cloudless zones, etc.).

It may be observed in this context that the program of measurements to be carried out on the way to the mesoseale area (and return to the base point) is highly essential. Synchronous measurements by means of two airplanes in the boundary layer of the atmosphere, measurements above and below the cloud layer, are of fundamental importance in evaporation of the systems of parametrizing the interaction between the atmosphere and the ocean. The use of two "radiation" airplanes makes it possible to render much more informative the content of the comprehensive programs of synchronous measurements from ships, buoys, ground stations, aircraft, and satellites, which should represent key measurements for RPA and GATE as a whole. /104

Figure 4 shows the approximate distribution of ships in the mesoseale area and its environs (scales A, B), this distribution characterizing the fundamental potential of ship measurements in the interests of RPA (it should be noted that the airplanes will be based in Dakar). In the international RPA [35] emphasis has correctly been placed on the need for setting aside a special group of vessels which will bear the primary responsibility for carrying out RPA (it is recommended that the northeastern portion of the area, which is nearest Dakar, be used for this purpose). Adoption of this recommendation is an important condition for successful conduct of the comprehensive synchronous measurement programs referred to in the foregoing. The vessels intended specifically for participation in the conduct of RPA, of course, should have onboard actinometric, spectral, aerosol, and other equipment equivalent to that mounted in the aircraft laboratories, as well as aerologic and actinometric radiosonde facilities. The international RPA [35] contains detailed information on the parameters to be measured, the measurement methods, and special instrument comparison. Detailed discussion is also devoted in this document to this problem of collection, storage and dissemination of data.

space during special RPA periods planned in advance will permit successful conduct of comprehensive synchronous observations in the interests of RPA and allied subprograms which are to represent the experimental basis for accomplishing the main tasks of GATE.

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